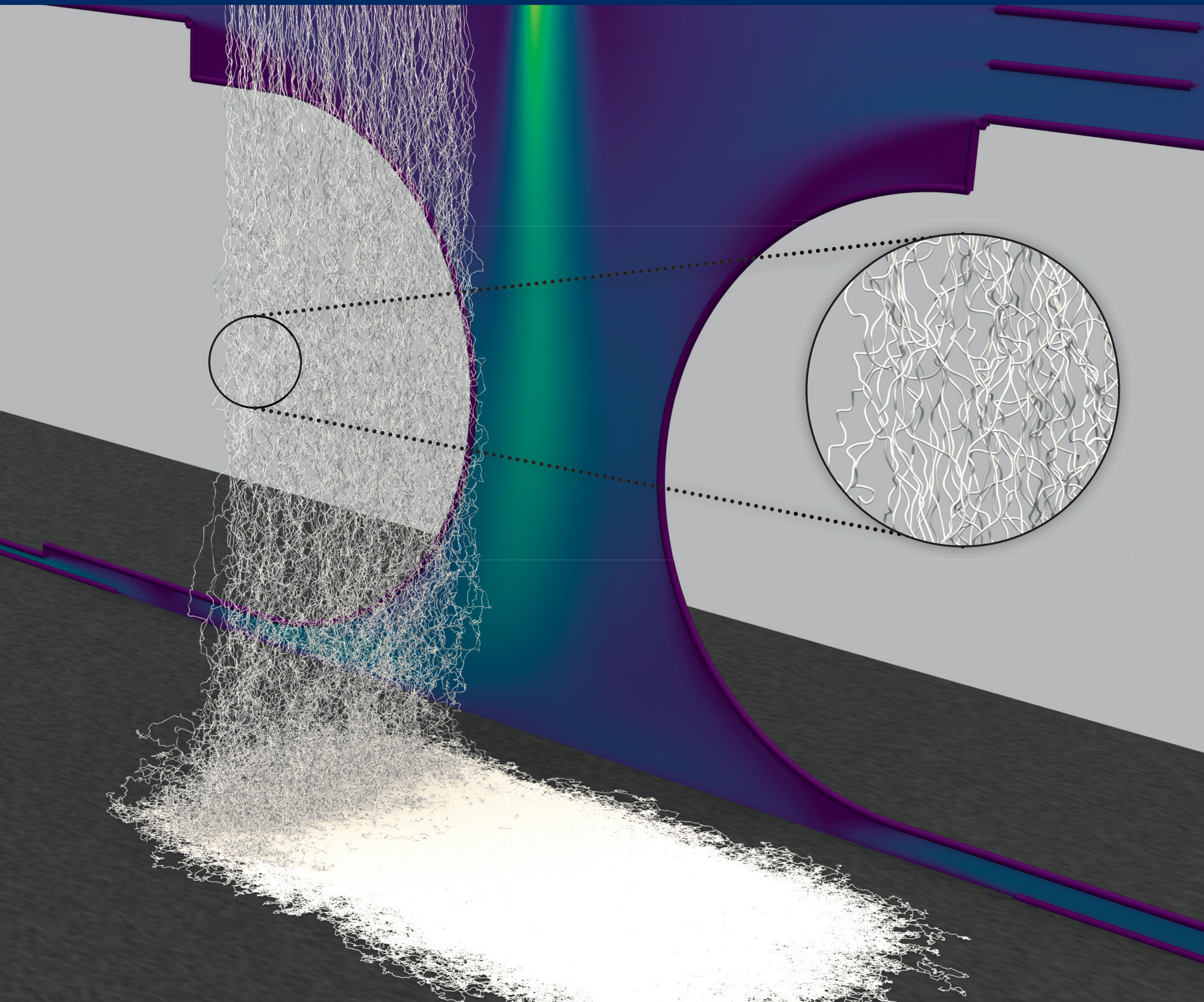
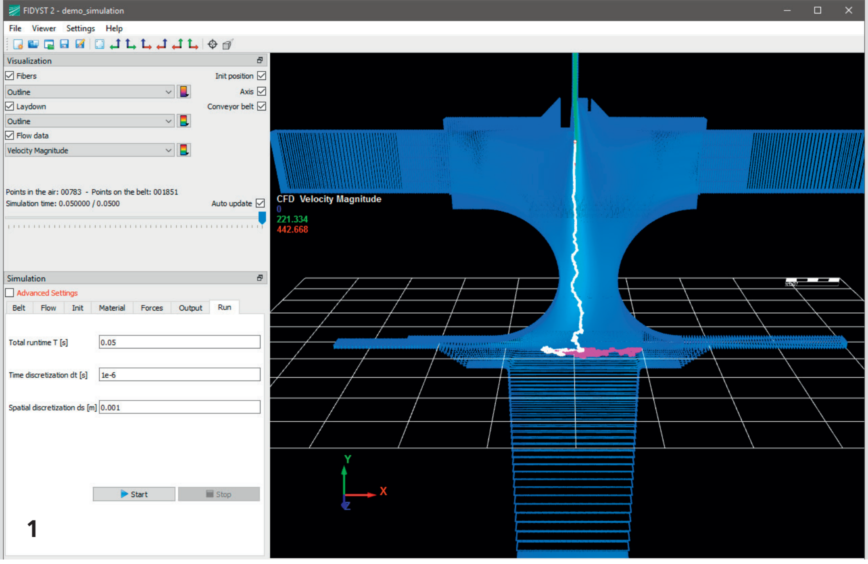
Fraunhofer ITWM

FRAUNHOFER INSTITUTE FOR INDUSTRIAL MATHEMATICS ITWM

FIDYST – FIBER DYNAMICS SIMULATION TOOL





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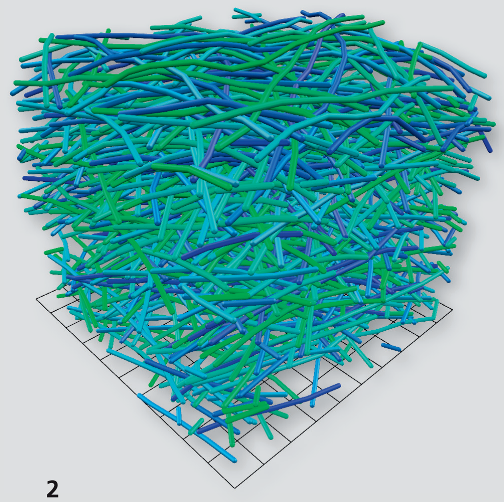

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1 *FIDYST with Graphical User Interface showing a spunbond airflow and filament simulation*

2 *Sample of a virtual spunbond nonwoven, base area 1 mm², height 0.85 mm*

$$(\rho A)\partial_{tt} r = \partial_s(T\partial_s r - \partial_s((EI)\partial_{ss} r)) + f_{ext}$$
$$\|\partial_s r\| = 1$$

In the field of technical textiles fibers, filaments, and yarns consisting of different materials are produced or processed. Examples are the production of nonwovens, glass wool, and yarns, as well as the processing of natural fibers. During the production and processing the filaments are subject to forces determining their movement. In order to be able to cover such processes by simulation, the Fraunhofer ITWM is developing the simulation tool FIDYST (Fiber Dynamics Simulation Tool). The simulation of the fiber dynamics enables additional potential for tailored process design and process optimization.

Fiber Dynamics

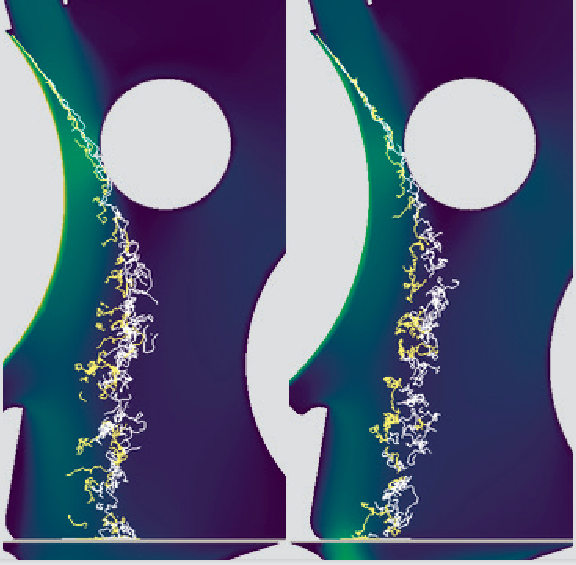
FIDYST is able to simulate the dynamics of elastic filaments subject to internal stresses and bending forces. The dynamics of an elastic fiber can be formulated by a Newtonian equation of motion. Apart from the internal stresses, bending forces and gravitation, the leading effect of air flow is of decisive importance here. The essential external factors influencing the fiber dynamics are aerodynamic forces and contact with machine components.

Aerodynamic Forces

In many production plants, the movement of filaments is mainly controlled by the properties of air flow. FIDYST allows for the integration of such flow data determined by simulations with commercial CFD tools, such as ANSYS FLUENT® or ANSYS-CFX®. FIDYST can process two-dimensional and three-dimensional flow data and can handle symmetric and periodic domains. Stationary as well as transient and periodic data sets are supported. Based on these data, the corresponding air drag forces on the filaments are computed. Besides the forces due to the deterministic main flow, FIDYST also computes the stochastic forces produced by turbulence. The respective model is based on the local turbulence data taken from the RANS flow simulation.

Collisions

During the processing, the filaments might be deviated or caught by firm or moving machine components. In order to handle the contacts with walls by FIDYST, the boundary surfaces can be made available as triangulated surfaces. The surfaces can be directly selected from the boundary elements of the corresponding CFD data set using the same mesh as for the flow simulation. Additionally, moving machine components are automatically handled using transient data sets. In order to simulate filament-wall contacts, the dynamic equations are extended by geometric constraints and corresponding Lagrange multipliers.



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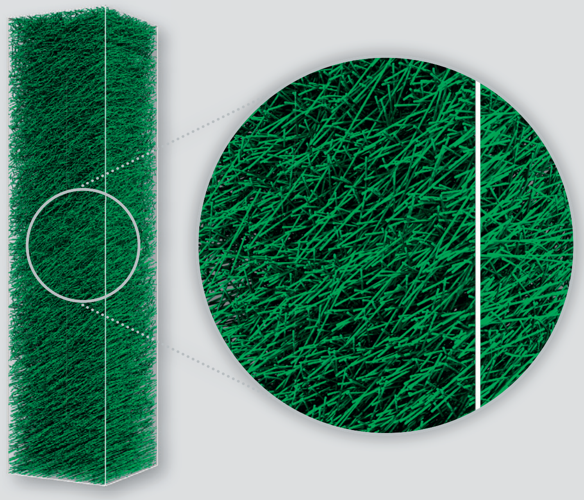

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Effects on the Air Flow

In typical spunbond applications, the air flow is so strong that the effect of fibers on the flow is of secondary importance and thus the air flow can be computed independently from the filament dynamics. The effect of the filaments on the flow can be neglected. In other processes like airlay, where there are large number of filaments or fibers involved during the process, the flow simulation must also account for the drag effect of the fibers. The effect of many fibers is converted into a source of momentum by homogenization. In this way, the FIDYST data with respect to the fiber movements are accounted for in the CFD simulation via a respective interface. With an iterative process, this can be used for a complete coupling of fluid flow and fiber dynamics. Fig. 3 shows the effects of fibers on the air flow in a coupled simulation for an airlay process.

Additional Features

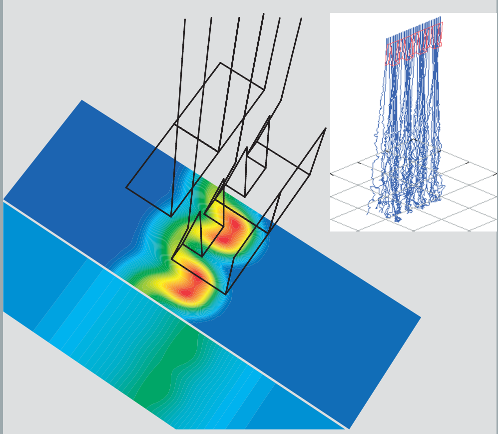
- Graphical user interface
- Interactive visualization
- Parallelized computation
- Batch processing for parameter studies
- EnSight™ format output for post-processing
- Generation of virtual nonwovens
- Post processing tools (base weight distribution, distribution of orientation, etc.)
- Export to GeoDict®, Abaqus®, CSV, etc.

Application Fields

- Control of filament and staple fiber dynamics
- Process optimization and design of new facilities
- Optimization of components like spinneret, cooling air, funnel
- Spunbond, meltblown, airlay
- Nonwovens, yarns, glass fibers

3 *Simulation of an airlay process (left) without and (right) with coupling the effect of fibers on air. Two fiber types: solid (white) and bicomponent (yellow)*

4 *Virtual airlay fabric ($1\,cm^2$ x 6 cm) showing a characteristic laydown profile in machine direction*



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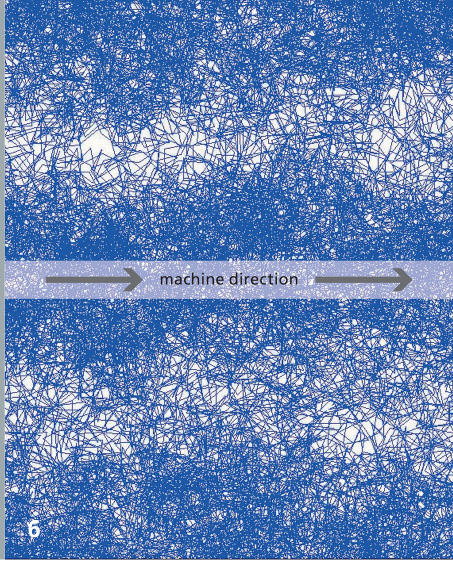

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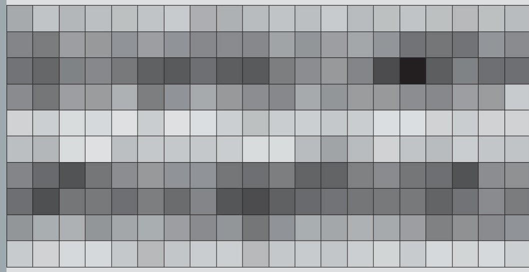

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5 *Turbulent air flow under slot and simulation of fiber curtain*

6 *Computed web structure*

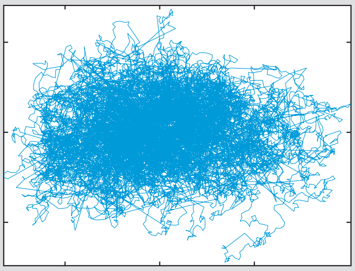
7 *Computed averaged base weight distribution*

Application for Nonwoven Processes

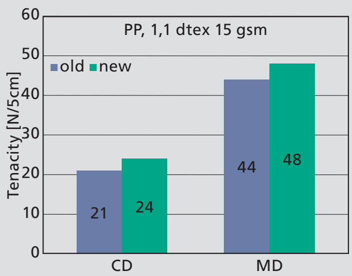
The simulation of fiber dynamics with FIDYST is always linked to the computation of fluid flow by standard CFD tools. The figures show an application for the spunbond technology of Oerlikon Neumag to determine the effect of so-called finger plates onto the nonwoven properties. The first graphic shows a sketch of the finger plates in the slot and visualizes the air speed in the middle of the laydown region and on the belt. The fiber dynamics in this free jet caused by the finger plates has been simulated using FIDYST. The results demonstrate a significant bundling of filaments together with fluctuations caused by turbulence of the air flow. The FIDYST simulation computes the resulting laydown. The computed web structure clearly shows that the bundling of filaments perturbs their distribution in cross direction leading to streets in machine direction with weak and dense regions. The typical cloudiness of nonwoven products is also present and can more easily be seen by the computed averaged base weight distribution.

Example for Constructive Design Based on FIDYST Simulations

We give a brief example how FIDYST can be used to generate new technical solutions. One output of FIDYST simulations is the full trace of single filaments in the nonwoven structure. These traces are analyzed with respect to the initial laydown positions observed from the slot. Their superposition leads to an elliptically shaped decomposition region. The length of semi-major and semi-minor axis is used as an indicative criterion to predict the tenacity of the resulting nonwoven. By simulating several potential constructive solutions the most promising variant has been identified. Oerlikon Neumag uses these results to construct a new web form. Its preliminary realization on Neumag's pilot line has shown an improvement of tenacity of about 15 %, particularly in CD direction.



Trace of single filament in nonwoven analyzed by transformation



Increase of tenacity by simulation based new forming zone (Neumag)

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